Visualizing
the Future
of Civil Aviation

ACES

Airspace Concept Evaluation System

ACES Development Team

- NASA Ames Research Center
- Raytheon, Network Centric Systems
- Intelligent Automation, Inc.
- Science Applications International Corporation
- Sensis, Seagull Technology

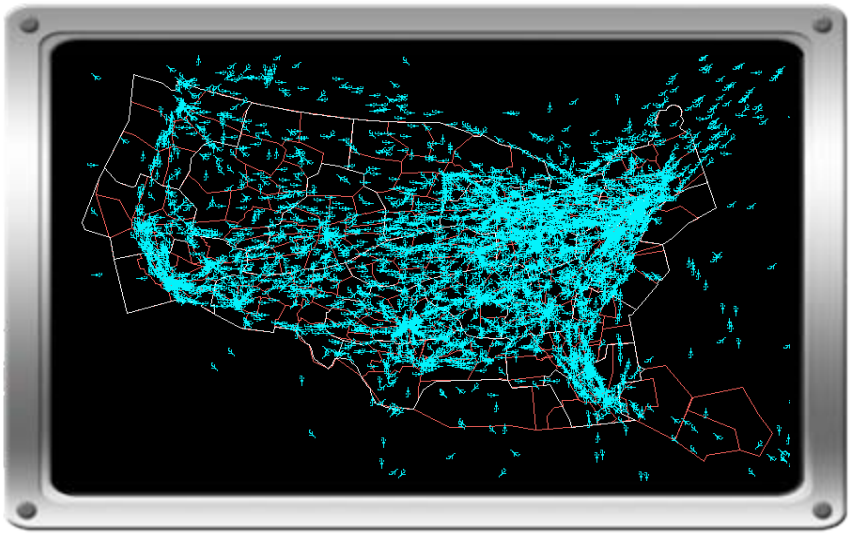
Agenda

- Motivation
- Description of ACES
- Airport and Airspace Constraints
- VAMS System-wide Concept Assessment
- Summary

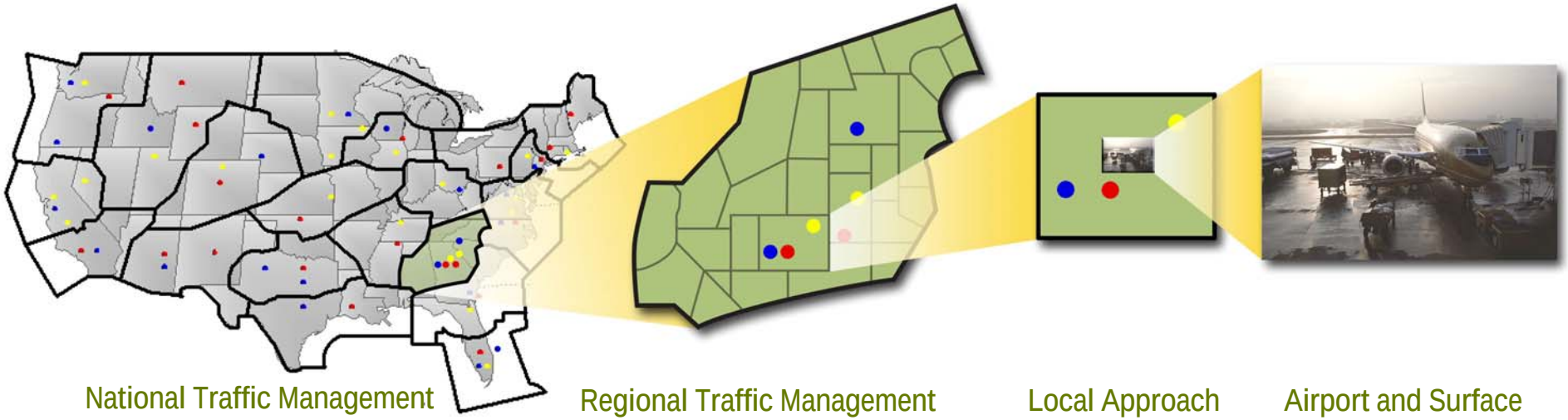
Motivation

- Assess system-wide impacts of airspace technologies and operation concepts for future demand scenarios

- Develop and refine new operational concepts



ACES Models All Domains of the NAS



National Traffic Management

Fast-time, nationwide gate-to-gate simulation of ATM-FD-AOC operations

- Full flight schedule with flight plans, 4-D gridded winds, gate-to-gate operations

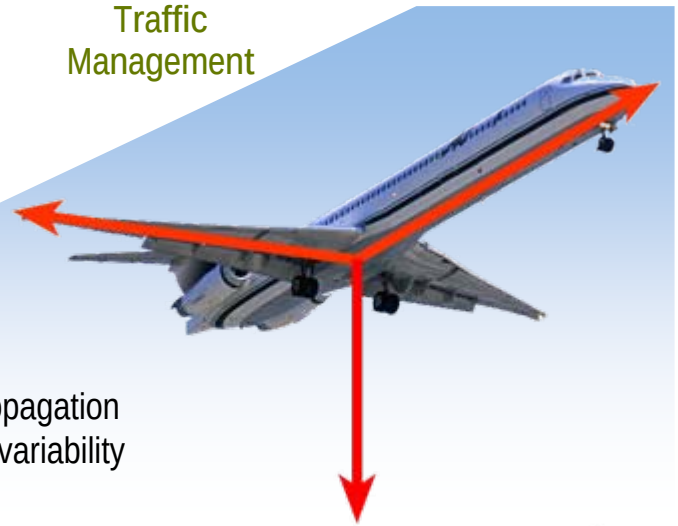
Regional Traffic Management

Thousands of participating agents:

• National	1
• Regional	20
• Local	100s
• Airports	100s
• Aircraft	10,000s
• Airlines	10s

Local Approach and Departure Traffic Management

Airport and Surface Traffic Management

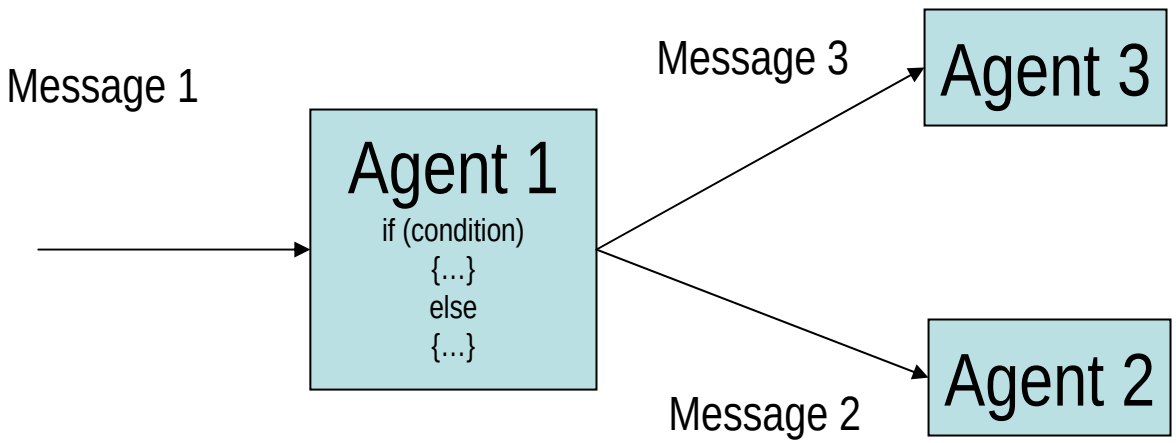


High Fidelity 4-DOF Trajectory Model

- ✈ Based on laws of physics
- ✈ Realistic pilot-based control laws
- ✈ Includes elliptic-Earth trajectory propagation
- ✈ Contains modeling for aircraft/pilot variability

Agents

- Autonomous piece of software
- Communicate with other agents via messages
- Make decisions based on events that occur within the system
- Messages are captured and stored for output

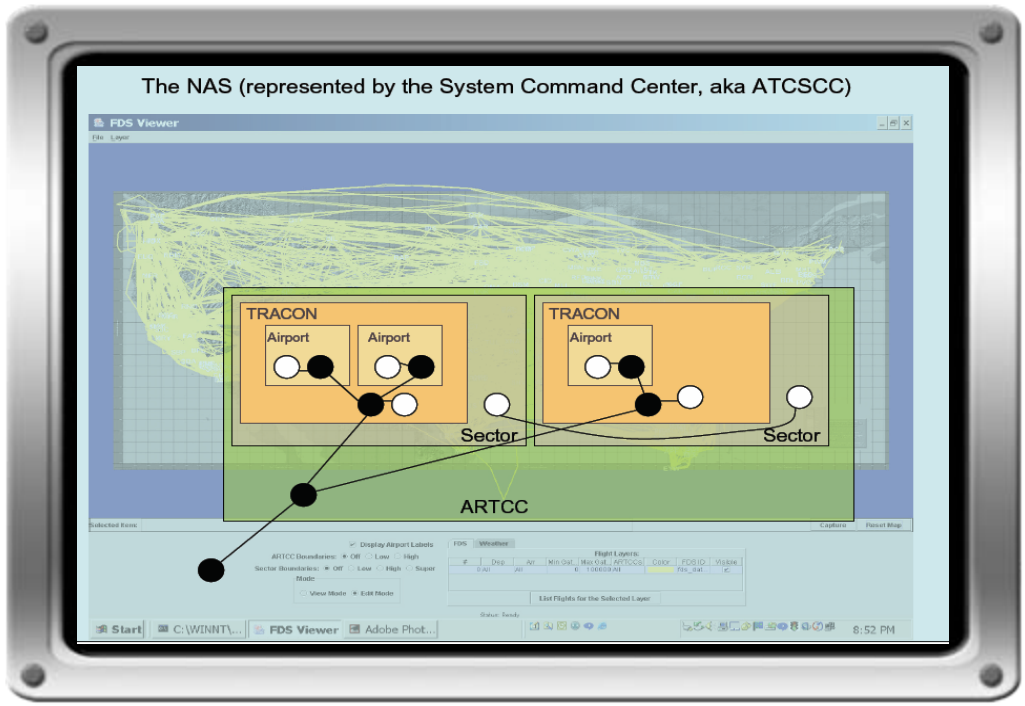


ACES Capabilities Facilitated by Agents

- Simulation of hundreds of thousands of flights
- Plug and play of new agents that model new aspects of the NAS
- Multi-fidelity modeling of different NAS domains

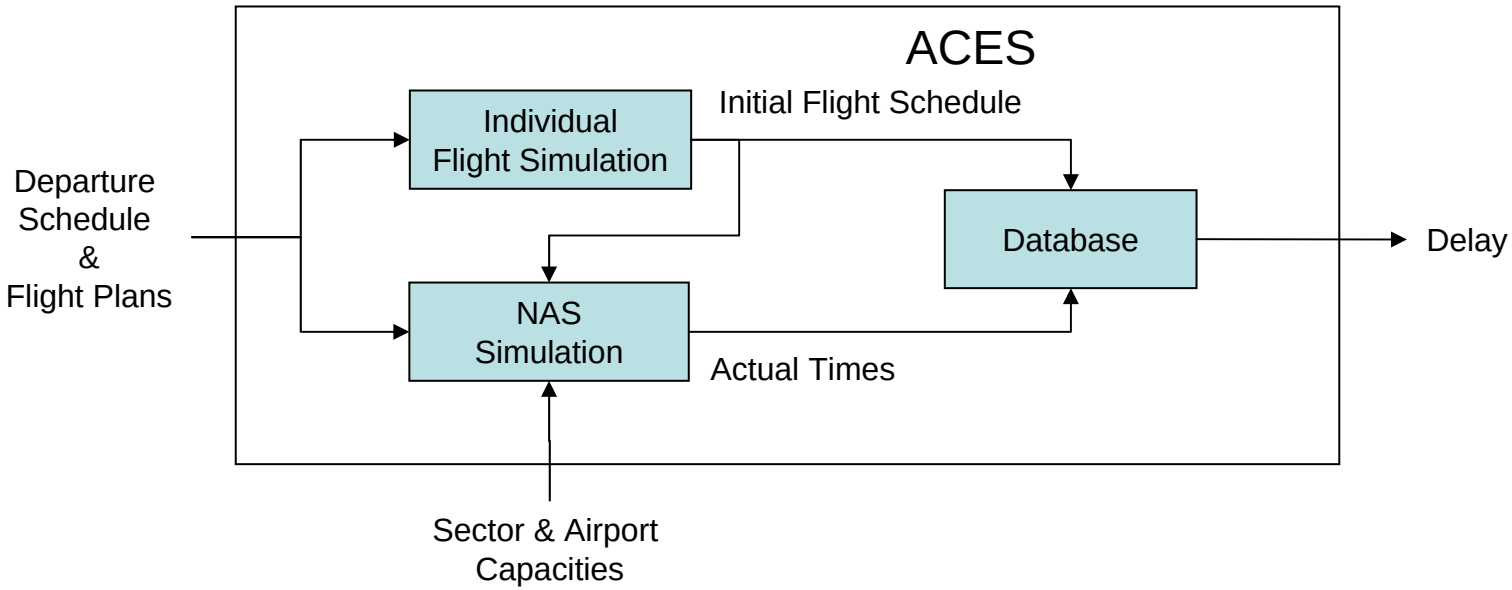
Agent Models in ACES

- Each entity in the National Airspace System (NAS) is modeled by an agent
  - Flights
  - AOCs
  - Airport ATC & TFM
  - TRACON ATC & TFM
  - En-route ATC &TFM
  - Command Center



- Agents model the physical and organizational layout of the airspace

ACES Block Diagram



ACES Modeling Capabilities

- Multi-fidelity modeling of the system
  - En-route – 4DOF trajectory modeling in 3D airspace
  - Airport/TRACON – node/link model
  - Detailed or aggregate runway models at airports
- Traffic flow management
- Automated conflict detection and resolution
- AOC
  - Cancellations
  - Tail tracking
- Winds

ACES Outputs

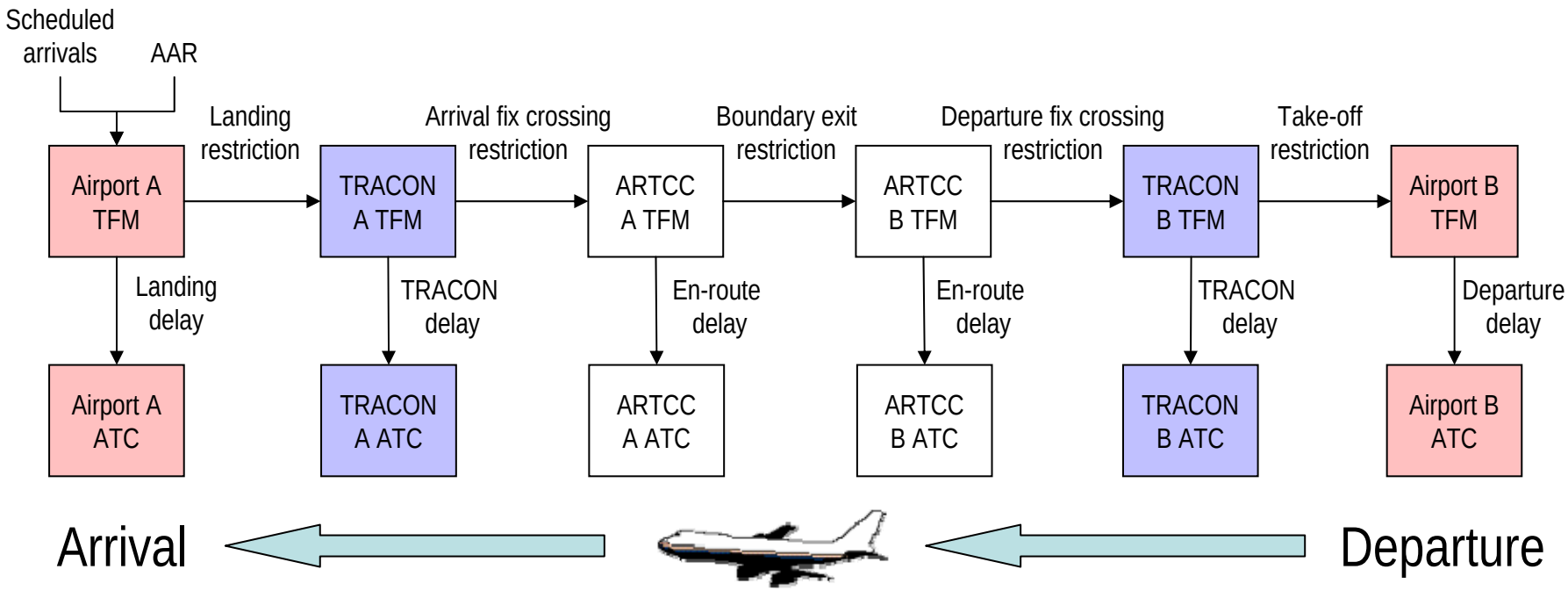
- Arrival & departure rates at specified points in the airspace or in an airport
- Sector and center flight counts
- Number, duration, and locations of delays
- Number, type, and location of flight deviations and conflicts
- Number of hand-offs, cancellations, and monitor alerts
- Models that ACES links with (open loop)
  - Noise Impact Routing System (NIRS) - population impacted by a given noise level in dB dnl
  - Emissions & Dispersion Modeling System (EDMS) - amount of CO, NOX, HC, and SOX per year
  - Communication, Navigation, and Surveillance model
    - Number of voice messages sent and lost and duration and delay of message
    - Surveillance position errors and navigation heading errors
  - Air MITAS – controller workload parameters

Traffic Flow Management

- Airport constraints
  - Airport arrival rate (AAR)
  - Airport departure rate (ADR)
- Sector constraint
  - Monitor Alert Parameter (MAP)

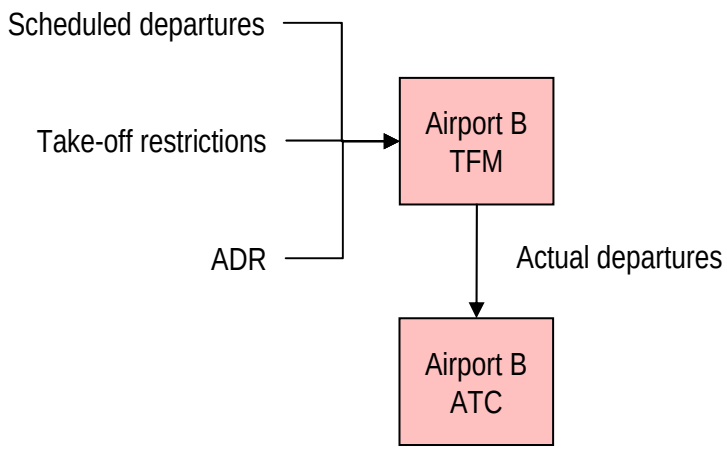
AAR Assessment

- Performed every 15 minutes over a 6 hour time horizon at every airport in the system
- Reschedules arrivals to maintain rates under AAR
- New arrival times are achieved by delaying flight upstream



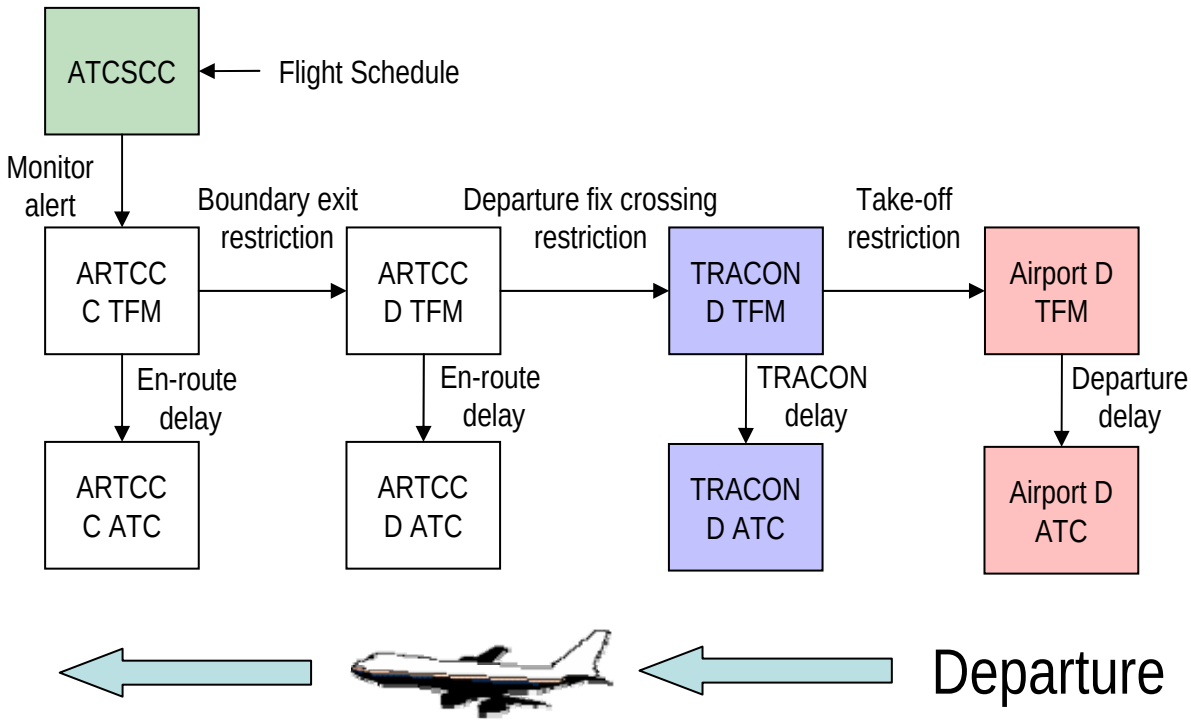
ADR Assessment

- Performed every 15 minutes over a 6 hour time horizon at every airport in the system
- Reschedules departures to maintain rates under ADR



Monitor Alert Assessment

- Performed every 15 minutes over a 6 hour time horizon at ATCSCC
- Passes monitor alerts to center TFM
- Center TFM delays last flight that enters over-loaded sector to maintain sector counts under their MAP value



Virtual Airspace Modeling and Simulation Project

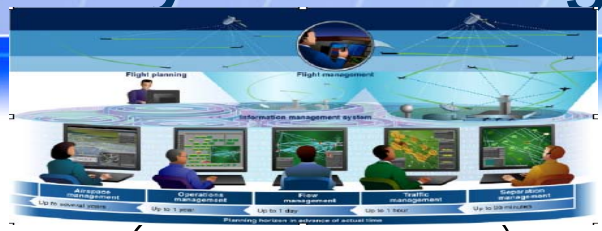
- Began in 2000
- Ended in 2006
- Created a system-wide concept consisting of 6 domain specific concepts
- ACES was built to assess the concepts
  - Explicit
  - Implicit

VAMS Capacity Increasing Concepts

System-level

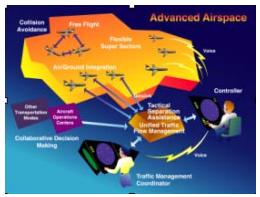
Metron – All - Weather

Seagull - Point-to-Point



En route

climb

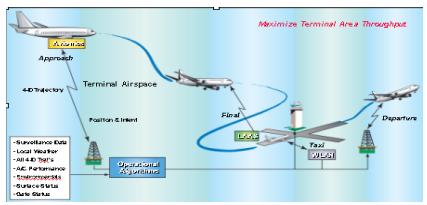


descent

NASA ARC - AAC

Terminal

takeoff

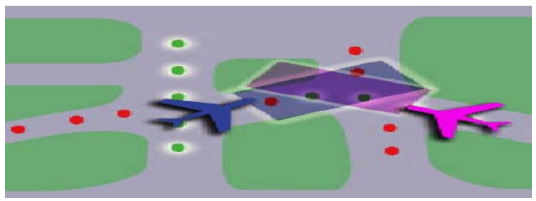


landing

NASA LaRC - Wake VAS

Raytheon - TACEC

taxi



taxi **Surface**

gate

Optimal Synthesis - SOAR

gate

Experimental Approach

- Considered three states of the NAS
  - Current Day capacity @ 1.0 and 1.3 demand
  - OEP v5 (2015) capacity @ 1.3 and 1.5 demand
  - Future (2025) capacity @ 1.0, 1.5, and 2.0 demand, with and without PTP

- Parameters representing operational capacities of these systems were combined with anticipated demand schedules to produce simulation data quantifying throughput and delay metrics
  - Each case evaluated in a perfect clear-weather day and a nominal weather day

Experimental Approach Continued

- Flight demand was grown using AvDemand and *70%* of available airport capacities for future cases
- Airports were modeled as nodal airports with unconstrained departure and arrival fix flows
- The same representative wind data was used for all cases

CD-PSCA Input Data

- Airport Capacities
  - Current Day based on published values, Benchmark 2004 report, and ASPM data
  - OEP v5 (2015) based on Benchmark 2004 report
  - Future (2025) based on combined input of concept developers
- Sector Capacities
  - Current Day based on current Monitor Alert Parameters (MAP)
  - OEP v5 (2015) developed through comparison of technologies with the Distributed Air Ground (DAG) concept
  - Future (2025) acquired as a combination of concept developer's inputs
- Airport Operating Conditions
  - All under VFR for clear weather day

Input Data Continued

- Future System-Wide Concept Representation
  - AAC represented as a 300% increase in current day sector capacities
  - *TACEC and Wake VAS were represented by increased airport capacities*
    - *TACEC implemented at 32/36 major airports*
    - *Wake VAS implemented at 37 major airports*
  - *PTP represented using modified demand data sets*
  - *SOAR concept provided Surface Traffic Limitation (STL) parameters*
    - *34 major airports*

CD-PSCA ACES Setup Conditions

- The basic experimental setup conditions for the CD-PSCA runs included the following:
  - ACES Build - 4.0.2_NASA
  - CD&R – Off
  - En Route Delay Maneuvers – On
  - Arrival Fix Spacing – Off
  - Arrival Fix TRACON Delay – Off
  - Departure Fix TRACON Delay – Off
  - AOC Operation – Off
  - Tail Tracking – Off
  - Surface Traffic Limitation – On
  - Airport mode – Nodal
  - Airport weather modeling – None, all VMC was assumed
  - En route weather modeling – None
  - Wind data – On, used Rapid Update Cycle data for May 17, 2002.

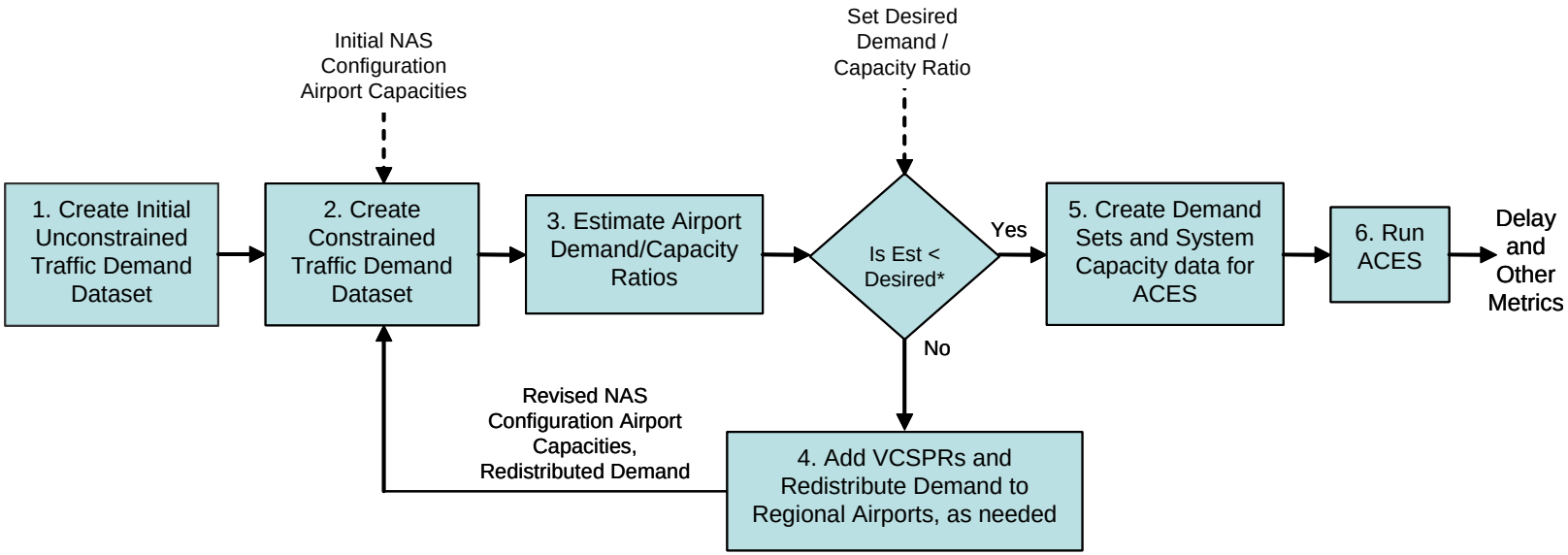
CD-PSCA Assessment Scenarios, Summer 2006

NAS Configuration	1x	1.3x	1.5x	2.0x
Current NAS (circa 2002)	X	X		
FAA OEP (circa 2015)	X	X	X	
VAMS SWC Study 1	X		X	X
VAMS SWC Study 2	X		X	X

SWC Case Study 1: SWC with a comprehensive collection of the SWC features and with TACEC implemented at 32 airports, but without the use of Regional Airports.

SWC Case Study 2: SWC with a comprehensive collection of the SWC features and with TACEC implemented at an additional 4 airports and with the use of Regional Airports to unload the busy hubs.

Process for Developing SWC Creating Demand Set (1.5x, and 2.0x)

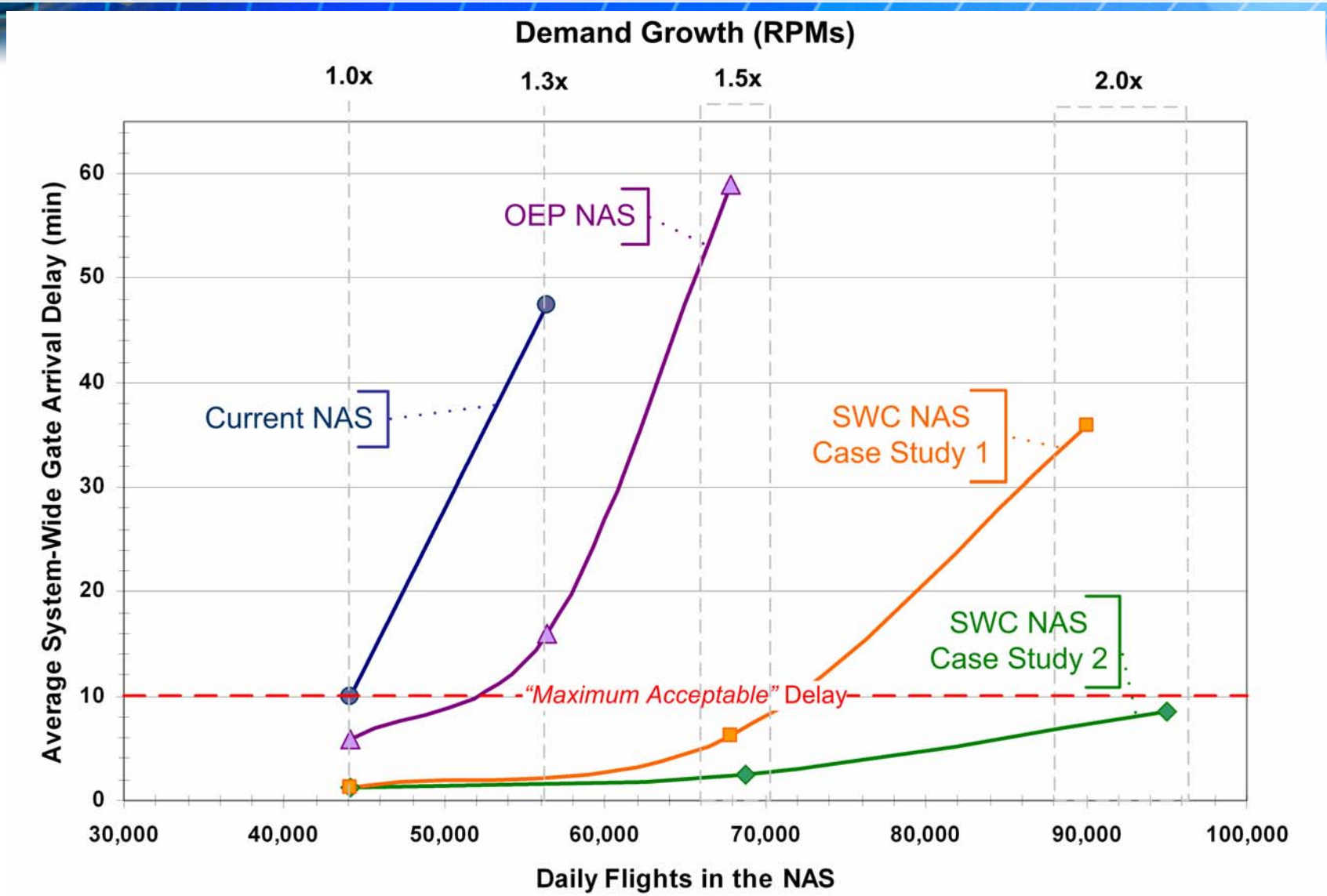


* Loop through Steps 2, 3 and 4 until demand / capacity ratio < desired or lowest level achievable

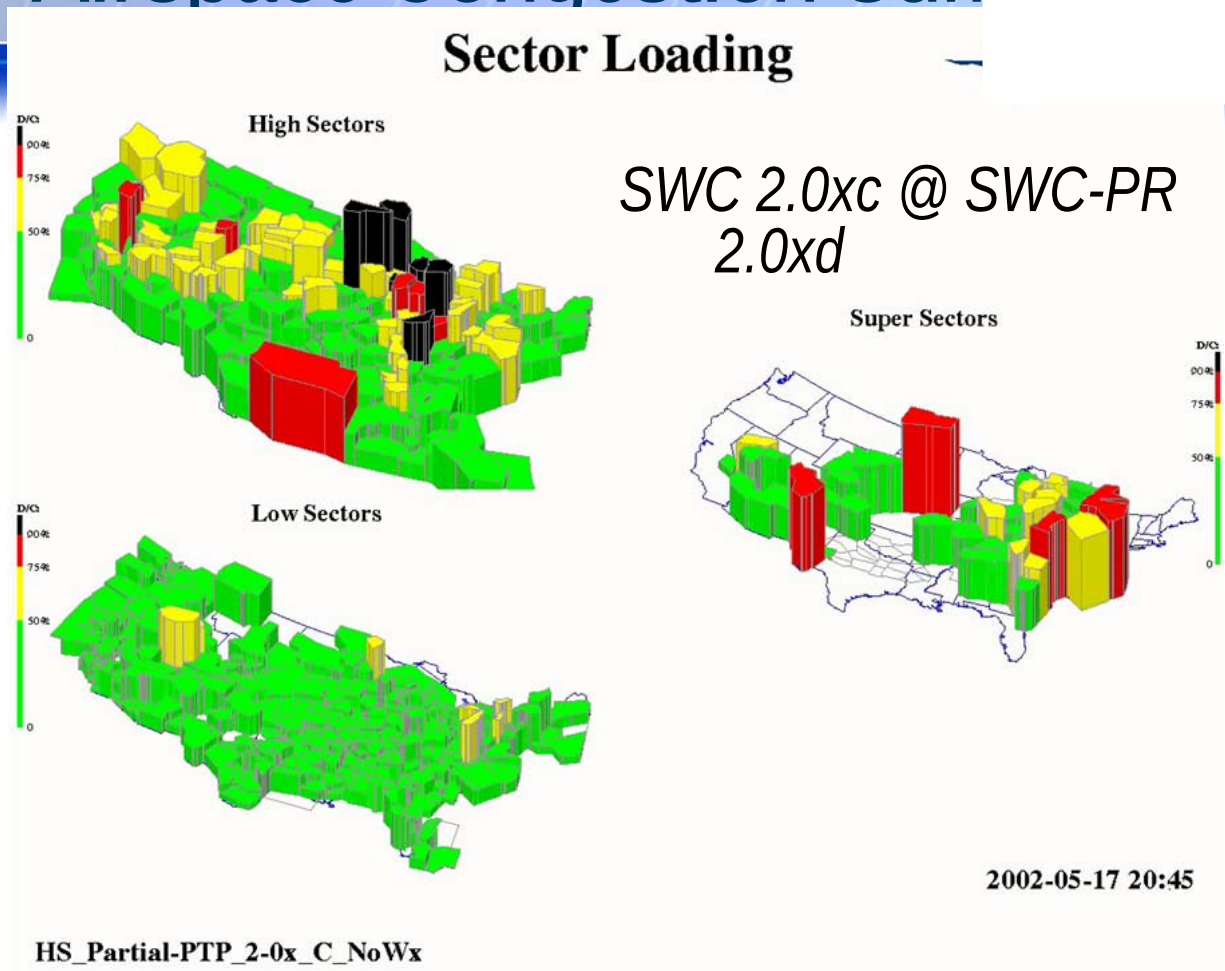
D/C Ratio for Most Overloaded Airports after applying the SWC Case Study 1 Airport Capacities

	SWC Case Study 1				SWC Case Study 1		
ID	1X	1.5X	2X	ID	1X	1.5X	2X
ATL	0.38	0.64	0.90	MDW	0.34	0.52	0.69
BNA	0.32	0.48	0.64	MSP	0.27	0.55	0.82
BWI	0.32	0.56	0.79	OAK	0.49	0.88	1.25
CLE	0.40	0.56	0.72	ORD	0.39	0.58	0.77
CLT	0.37	0.57	0.78	PHL	0.33	0.66	0.98
CVG	0.22	0.40	0.58	PHX	0.32	0.52	0.71
DCA	0.23	0.39	0.54	SAN	0.59	0.96	1.32
DEN	0.30	0.55	0.39	SAT	0.35	0.59	0.60
EWR	0.76	1.19	1.66	SEA	0.36	0.51	0.68
FLL	0.37	0.62	0.92	SFO	0.32	0.49	0.67
IAD	0.2	0.59	0.97	SJC	0.32	0.53	0.71
JFK	0.35	0.72	1.09	SNA	0.42	0.70	0.95
LAS	0.43	0.78	1.12	TEB	0.36	0.55	0.49
LAX	0.39	0.62	0.87	TPA	0.38	0.60	0.55
LGA	0.40	0.45	0.52				

CD-PSCA Assessments, Delay Results

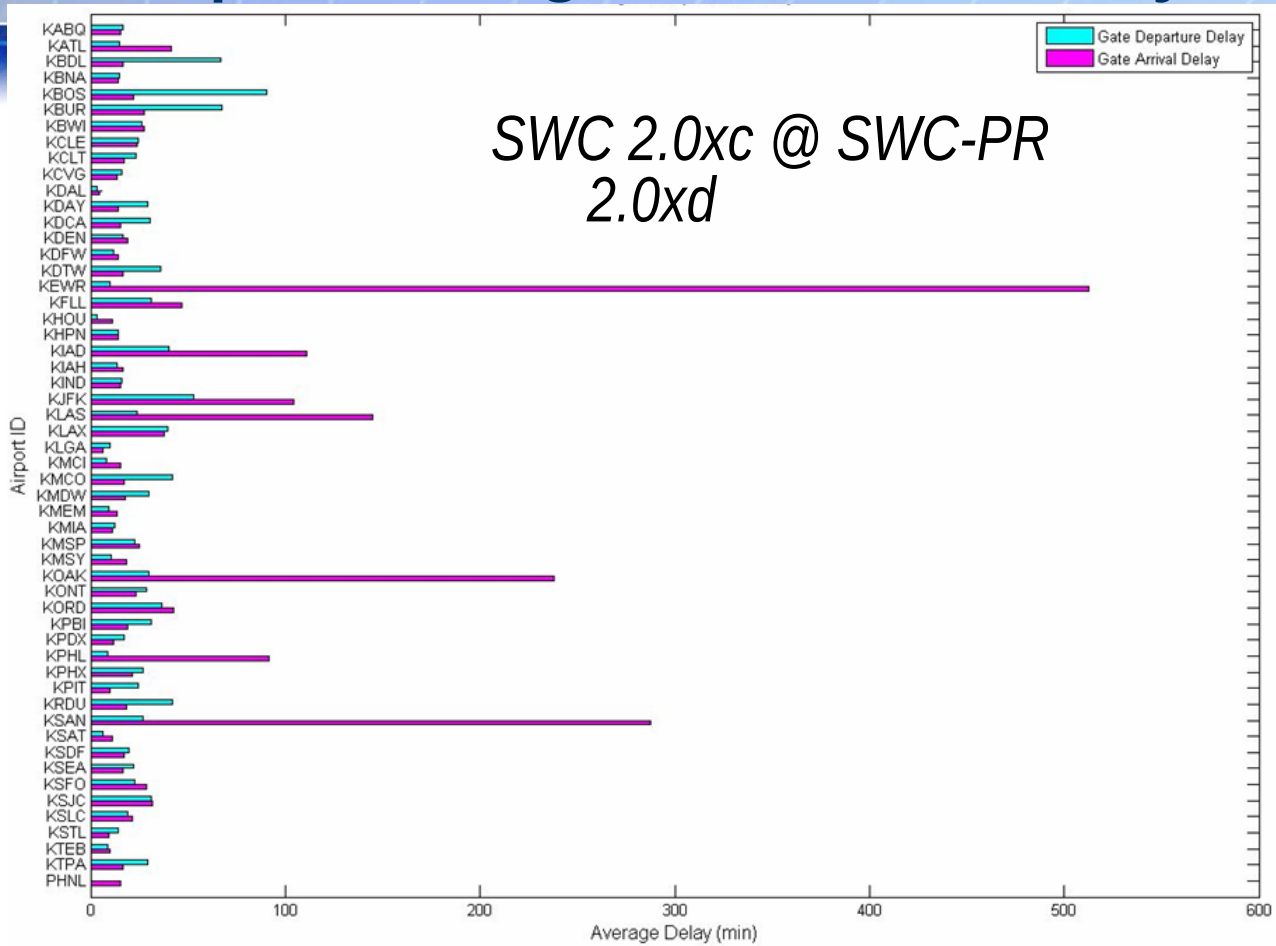


Airspace Congestion Summary



- Airspace capacity improvements delivered by AAC makes airspace congestion manageable, with some lingering problem high airspace sectors in and around ZAU

Airport Congestion Summary



- Despite low 8.6min/flt NAS-wide delays, some airports are still experiencing delays > 2hrs/flt:
  - EWR, SAN, OAK, LAS

Summary

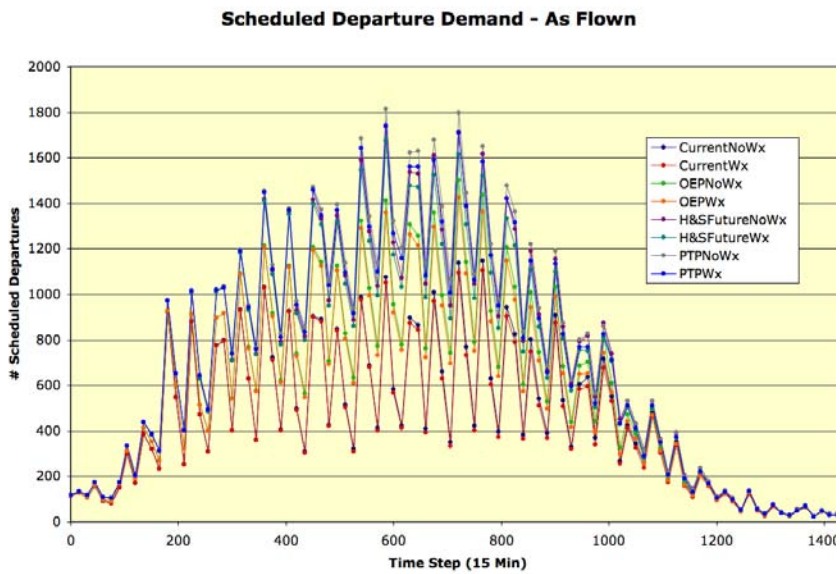
- ACES is a powerful agent-based simulation of the national airspace system
  - Constrains airport arrivals and departures
  - Constrains sector flight counts

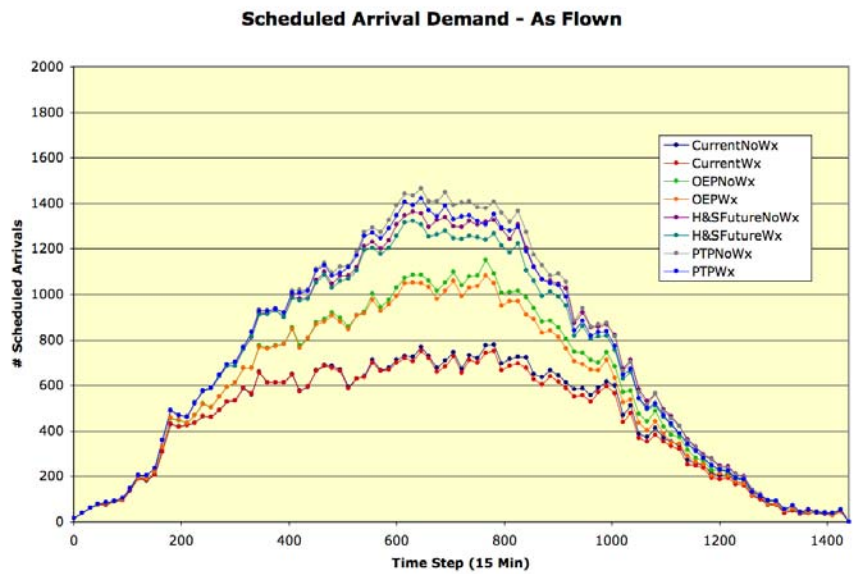
- Results of the assessment showed that the system-wide concept was able to accommodate 2x traffic levels
  - De-peak traffic demand schedule
  - Off load traffic at major airports to regional airports
  - Add new runways

Analysis

- Flight Demand Data Sets

	Current	OEP	Future 1.5X	PTP 1.5X
Scheduled Flights	**47,027**	**57,225**	**68,668**	**71,590**
% Over Current Day	**-**	**22%**	**46%**	**52%**





Analysis

	Scenario Description							
	Current Day		OEP		Future 1.5		PTP 1.5	
Metric	No Wx	Wx	No Wx	Wx	No Wx	Wx	No Wx	Wx
Flights Flown	43,016	41,927	56,004	54,102	67,341	64,903	69,744	67,651
Domestic flights	40,394	39,319	52,543	50,679	63,047	60,656	65,441	63,359
International flights	2,622	2,608	3,461	3,423	4,294	4,247	4,303	4,292
Operations at Benchmark airports	28,919	28,044	38,758	37,233	47,728	45,780	47,174	45,602
% Operations at Benchmark airports	67.2%	66.8%	69.2%	68.8%	70.8%	70.5%	67.6%	67.4%
Total Number of Passengers	2,116,657	2,049,381	2,866,360	2,725,368	3,578,866	3,434,124	3,391,281	3,281,879
Flights < 2 Hrs Delay	42,491	40,612	55,372	52,066	66,246	61,094	69,440	64,097
# of Flights > 15min Late	5938	6531	12146	13887	9287	14174	5876	12987
Average Airborne Time	106.87	103.52	116.29	111.30	126.30	120.70	115.57	111.36
Average Gate Dep Delay	5.42	17.46	6.96	20.30	7.24	27.91	3.01	25.34
Average Taxi-Out Delay	1.93	1.37	3.94	14.63	8.24	5.67	7.44	8.90
Average Airborne Delay	0.31	0.31	0.65	0.55	0.46	0.49	0.43	0.35
Average Taxi-In Delay	2.48	1.86	5.05	5.27	2.40	2.03	2.18	2.16
Average Gate Arrival Delay	10.14	21.00	16.60	40.75	18.34	36.10	13.07	36.75

Experimental Approach

- Considered three states of the NAS
  - Current Day
  - OEP v5 (2015)
  - Future (2020)

- Parameters representing operational capacities of these systems were combined with anticipated demand schedules to produce simulation data quantifying throughput and delay metrics
  - Each case evaluated in a perfect clear-weather day and a nominal weather day

- Flight demand was grown using AvDemand and 100% of available airport capacities
  - Current Day ~47,000, OEP ~57,200, Future ~68,700, PTP ~71,600 flights
  - Two 2020 demand schedules were produced: one representing a hub-and-spoke business model, the other representing a Point-to-Point business model

Experimental Approach Continued

- Airports were modeled as nodal airports with unconstrained departure and arrival fix flows
- The same representative wind data was used for all cases
- Weather was implicitly modeled by adjusting sector capacities as a function of weather severity

Input Data

- Airport Capacities
  - Current Day based on published values, Benchmark 2004 report, and ASPM data
  - OEP v5 (2015) based on Benchmark 2004 report
  - Future (2020) based on combined input of concept developers
- Sector Capacities
  - Current Day based on current Monitor Alert Parameters (MAP)
  - OEP v5 (2015) developed through comparison of technologies with the Distributed Air Ground (DAG) concept
  - Future (2020) acquired as a combination of concept developer's inputs
- Airport Operating Conditions
  - All under VFR for clear weather day
  - Operating states of VFR/IFR defined in quarter hour increments for the nominal weather day

Input Data Continued

- Future Blended Concept Representation
  - AAC represented as a 200% increase in current day sector capacities
  - TACEC and Wake VAS were represented by increased airport capacities
    - TACEC implemented at 24 major airports
    - Wake VAS implemented at 37 major airports
  - PTP represented using modified demand data sets
  - SOAR concept provided Surface Traffic Limitation (STL) parameters